# Eye formation in cheese – C-1

Technical Bulletin

By Kristian Elsborg, Marketing Manager, Cheese Cultures

3 September 1996 – Revised on Januaryr 2002

*Keywords:* cheese, eye formation, citrate fermentation, and gas diffusion

In continental cheeses the eye formation is regarded as an important aesthetic and visual property.

This brief literature study describes the initial microbiological and physical processes of eye formation. Finally some examples of the factors influencing the quality of eye formation and a description of the most frequent texture defects of cheese are cited.

## Cheese types

### Cheese with irregular eyes

Cheese with irregular eyes is characterized by a large number of small eyes of the size of a rice grain. During filling of the cheese forms atmospheric air is worked in between the cheese grains, whereby the grains are prevented from uniting completely. $CO_2$ expelled during the microbiological process will then enlarge the eyes. Havarti, Tilsiter, Esrom, Port Salut etc belong to the group of cheese with irregular eyes.

### Cheese with regular eyes

Few, but large eyes characterize cheese with regular eyes as the curd is pressed under the surface of the whey. The resulting compact texture of the curd gives way to only few eyes which then grow larger due to the pressure released by the $CO_2$. Gouda, Danbo, Edam, Samsø etc belong to the group of cheese with regular eyes. The following description primarily focuses on cheeses with regular eyes.

### Gas-producing conversions

The gas pressure, which makes the eyes "grow" during the maturation phase, is a result of microbiological conversions from the starter culture added and from air dissolved in the cheese milk. However at this stage of the process additional unverifiable and/or unwanted gas formation caused by the secondary micro flora may occur:

## Starter culture

*Leuconostoc mesentorides subsp cremoris*

$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_3H_6O_3 + 2C_2H_5OH + \underline{2CO_2}$
Lactose Lactate Alcohol

*Lactococcus lactis subsp diacetylactis and*
*Leuconostoc mesentorides subsp cremoris*

$2C_6H_8O_7 \rightarrow 2C_2H_4O_2 + C_4H_8O_2 + \underline{4CO_2}$
Citrate Acetic acid Acetoin

## Secondary Flora

*Heterofermentative Lactobacillus*
Lactose $\rightarrow CO_2$ + lactate, etc

*Coli*
Lactose $\rightarrow \underline{CO_2}$ + lactate + acetic acid, etc

*Propionic acid bacteria*
Lactate $\rightarrow \underline{CO_2}$ + propionic acid + acetic acid, etc

*Clostridium tyrobutyricum*
Lactate $\rightarrow \underline{CO_2} + \underline{H_2}$ + butyric acid, etc

*Lactobacillus casei* types
Lactate + $O_2 \rightarrow CO_2$ + acetic acid + $H_2O$

## Physical aspects of eye formation

As soon as $CO_2$ is released from the microbiological process it will together with air be partly absorbed in the liquid phase of the cheese and partly in the surrounding curd.

When the point of saturation of the cheese moisture has been reached the excess gas will diffuse against some of the largest nuclei sites or naturally occurring pinholes or, in worst case, completely diffuse out of the cheese. These nuclei sites and pin holes may be caused by kneading in of atmospheric air or captured whey which is being absorbed by the curd and therefore leaves an empty space.

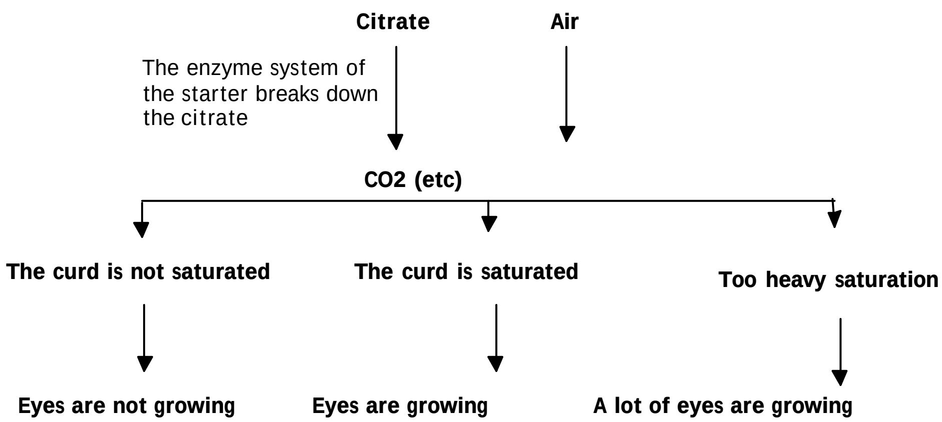
The phenomenon can be explained as follows (H H Lund, 1978):

"For air bubbles in liquids the following law applies for the pressure that influences the bubble:

$$\text{pressure} = \frac{2 \times \text{surface tension}}{\text{radius of bubble}}$$

According to this law eyes will only be formed if nuclei sites are already present. Consequently released gases in the cheese will assemble in the already existing empty spaces, the smaller the radius of the bubble, the larger the pressure required to make the bubble grow. If the gas formation takes place fast the diffusion through to the initially growing eyes may not be able to keep pace with the formation and the pressure may then increase to the extent that small bubbles may cause several eyes in the cheese."

On basis of the above we may conclude that the time at which the gas formation takes place and the gas pressure are essential parameters for the quality of the eye formation.




## Factors to obtain satisfactory eye formation

### 1) Few pinholes

Avoid too strong intermixture of air in the milk and between the cheese grains during pressing.

### 2) Suitable resistance against a growing eye

Higher or lower viscosity will result in more or less physical resistance against the extension of the hole. The viscosity depends on factors such as:

a) Water content
b) Fat content and amount of iodine
c) Temperature
d) Decomposition of casein

### 3) Suitable pressure in the cheese

The formation of $CO_2$ is to take place at a suitable speed so that saturation occurs and so that only a suitable amount of growing eyes will absorb $CO_2$.

## Regulation of the eye formation

As mentioned earlier air and $CO_2$ are main responsible for the gas pressure in cheese. In practical terms the regulation of eye formation is closely related to the regulation of $CO_2$. Therefore **a suitably slow fermentation of the citrate gives suitably few eyes and a regular eye formation** as $CO_2$ is formed from the citrate fermentation of the starter culture.

### Citrate fermentation

The speed of the citrate fermentation depends on several factors:

1. The amount of *Lactococcus lactis* subsp *diacetylactis* and *Leuconostoc cremoris* as well as the ratio of these strains in the starter culture. Generally *Lactococcus lactis* subsp *diacetylactis* strains break down citrate faster than *Leuconostoc cremoris* strains.

LD cultures consist of acidifying *Lactococcus* strains as well as citrate-fermenting strains *Lactococcus lactis* subsp *diacetylactis* and *Leuconostoc cremoris.* LD cultures are used for cheese in which a fast citrate fermentation and more eyes are wanted like in e.g. some Gouda types.

CHR. HANSEN

L cultures do not contain *Lactococcus lactis* subsp *diacetylactis* and are used for cheese in which slower citrate fermentation and few eyes are wanted like in e.g. Edam cheese.

2. The acidification activity of the starter culture affects the enzymatic citrate breakdown, as it is pH dependent. A faster pH drop results in - other things being equal - faster citrate fermentation and thereby earlier $CO_2$ formation.

3. The temperature during the cheese process as the enzymatic process is temperature dependent.

Below follow example of the influence of some important factors on the residual citrate content after 24 hours on the basis of standard Danbo 45+ cheese making (MOS 3.31 Cheese Simulation Program (1992), Dalum Technical Dairy School):

### Diacetylactis content of the starter culture
(percentage of *Leuconostoc* unaltered)

Approx 25% *Diacetylactis* 1087 mg/kg citrate
Approx 2.5% *diacetylactis* 1664 mg/kg citrate

### pH at cooling (12°C water/salt brine)

pH 6.04 1087 mg/kg citrate
pH 5.94 933 mg/kg citrate
pH 5.85 797 mg/kg citrate
pH 5.77 677 mg/kg citrate

### Change of cooling temperature

20°C water 767 mg/kg citrate
18°C water 847 mg/kg citrate
16°C water 927 mg/kg citrate
14°C water 1007 mg/kg citrate
12°C water 1087 mg/kg citrate
10°C water 1167 mg/kg citrate

### Influence of temperature on gas pressure and eye formation

The cheese grains will swell during cooling and thereby absorb "loose" whey, which leads to a better melting together of the curd and thereby fewer eyes. During salting and storage the temperature affects the firmness of the cheese and the resistance against the eye formation.

The temperature affects the solubility of $CO_2$ and thereby the saturation point in the curd as shown in the example:

| Temperature | Solubility in the liquid phase |
|---|---|
| 5°C | 3.35 g $CO_2$/l water |
| 10°C | 2.32 g $CO_2$/l water |
| 15°C | 1.97 g $CO_2$/l water |
| 20°C | 1.69 g $CO_2$/l water |

*Table 1. Solubility of $CO_2$ at different temperatures (H H Lund, 1978)*

In practice it has shown that the citrate content in cheese after 24 hours corresponds well to the quality of the eye formation in cheeses with regular eyes. Different results are available in the tables below from the Danish Government Dairy Research Institute, Hillerød and recommendations from NIZO:

| mg/kg residual citrate in 24 hours old Danbo cheese | Eye formation |
|---|---|
| < 300 | Over-set, shell eyes |
| 300 – 900 | Nice eyes |
| > 900 | Few eyes or blind |

*Table 2. Recommended level of residual citrate in 24 hours' old Danbo cheese (Danish Government Dairy Research Institute, Hillerød)*

| Residual citrate in Gouda cheese after | LD culture | L culture |
|---|---|---|
| 24 hours | 250-400 mg/kg | 1200-2000 mg/kg |
| 14 days | < 100 mg/kg | 800-1200 mg/kg |

*Table 3. Recommended level of residual citrate in Gouda cheese (NIZO-nieuws 1985, no 3)*

CHR HANSEN

## Most common texture defects

### Edge holes

Edge holes are characterized by small irregular eyes in the outer edges of the cheese and are considered to be mechanical defects. Generally the defect is due to poor melting together of the curd as a consequence of either air or whey accumulations or too early cooling.

The defect may be caused by the following factors:

1. Absorption of air during pumping and pre-pressing from e.g. leaking pipes, pumps or too low whey level resulting in too many eyes and thereby edge holes.
   Too heavy pre-pressure in automatic press towers can cause air intake in the cheese block. Whey levels and pressure on the cheese curd in press towers must be consistent.

2. Too vigorous cooling of the curd during pre-pressing in e.g. press vats or casomatic types may result in too poor melting of the cheese grains and too many eyes. The same applies if cold forms or covers during pressing are used.

3. Too high pressure may result in too early rind formation, which encapsulates whey and finally leads to unwanted fermentation. Too low pressure may result in poor melting together of the curd.

4. By salting too early the salt solution may enter too early whereby the space between the cheese grains increases and edge holes may occur. This may be remedied by cooling in either cold water or by air-cooling.

5. By rough handling of the pre-pressed cheese when e.g. transferring the cheese to the forms.

### Overdeveloped eyes, blowing

The eyes of the cheese are heavily over dimensioned. The cheese may be the size of a football and the curd may be blown.

Blowing is often due to a contamination in the cheese. This literature study distinguishes between early and late blowing.

Early blowing occurs within the first 48 hours of the cheese making and is often due to infection of coli bacteria. They ferment the lactose and release large amounts of $H_2$. Often the defect is followed by a strong and penetrating unclean smell. The coli bacteria are destroyed by low pasteurization and are therefore regarded as a post-infection of the milk due to leaking pipes, pumps or usually due to defects in the cooling part of the pasteurizer.

Late blowing occurs later in the ripening process of the cheese, most often after at least three weeks of storage and is primarily due to infection of propionic acid bacteria or *Clostridia*.

*Clostridia* are spore forming, lactate-fermenting bacteria and release large amounts of $H_2$. They infect the milk at the farmer where they are propagated via the feed, often in the silage. *Clostridia* are pH sensitive and therefore they grow best late in the ripening period. Along with the *Clostridia* infection there will be an unpleasant butyric acid smell.

Infection of propionic acid bacteria is often easy to trace as the characteristic "nutty" Emmentaler flavor follows the infection. Propionic acid bacteria grow poorly < 20°C, ferment lactate and are pH sensitive as low pH values inhibit the growth. Therefore the problems with propionic acid often occur late in the storage period. Sometimes increasing the pasteurization temperature may solve the problem.

Addition of nitrate or lysozyme inhibits the growth of *Clostridia*.

### Few eyes, compact

The defect can be caused by lack of gas forming bacteria or addition of too much salt/saltpeter, which inhibits the development of these bacteria. In addition the process technology used is an important consideration. Changing the growth conditions of the bacteria might solve the problem, using a different culture e.g. LD culture, higher storage temperatures or changing the salt conditions.

### Many eyes

The defect is often due to release of $CO_2$ at a too early stage in the process at which the curd is not yet adequately fused, having a consistency, which gives viable diffusion conditions. This can be caused by too fast citrate breakdown often due to an imbalance in the starter culture because of too high content of *Diacetylactis*. Too acid manufactured cheese may cause skin formation on the cheese grains and thereby poor melting together ability. Too rough treatment of fresh cheese.

A lower storage temperature may remedy the problem.

## Small eyes

Small eyes can be due to a too low content of citrate-fermenting bacteria or a too low storage temperature. A too low content of CO2-producing bacteria or other factors preventing an adequate pressure in the curd may also cause small eyes.

## Slits

Larger or smaller slits or fissures are seen in the curd.

A too strong acidification may result in leaching of Ca++ and thereby a less elastic curd which does not yield to the CO2 pressure. Large temperature fluctuations during storage or shipment may cause the problem. Finally slits could be due to blowing from e.g. *Clostridia*.

### References

1/ H H Lund "Citratforgæringshastighedens indflydelse på huldannelsen i opstukken ost" (Thesis 1978), Royal Agricultural University of Copenhagen.

2/ "MOS 3.31" (1992), Dalum Technical Dairy School.

3/ M D Norholt and J Stadhouders "Microbiologische en biochemische normen voor de bereiding van Nederlandse kaassoorten II " (NIZO-nieuws 1985, no 3).

### Further literature

1/ W Wagner Nielsen "Omdannelser i ost under syrning og modning" (1994), Royal Agricultural University of Copenhagen.

2/ J M Buch Kristensen "Osteteknologi" (1986), Dalum Technical Dairy School.

3/ J C Akkerman et al "Holes in Dutch-type cheese. 1. Conditions allowing eye formation" (Neth Milk Journal 43, 1989)